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COUPLING SYSTEM DESIGN OPTIMIZATION
A Survey and Assessment of Automatic Coupling Concepts for Rail Freight Cars
Volume I: Executive Summary

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FINAL REPORT

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16. Abstract

The purpose of this study is to provide an independent identification, classification, and analysis of significant freight car coupling systems concepts offering potential for improved safety and operating costs over the present system.

The basic method of approach was to make a comprehensive search as a prerequisite to establishing significant coupler concepts which would be used to formulate candidate coupling systems. The search program consisted of a literature search, a patent search, and railroad industry interviews.

Coupling development efforts have been decreased due to changing usage and profitability of the American railroads. The functional concepts of existing development efforts range in sophistication from increasing the gathering range of the present coupler system to providing automatic train air connection and a complete redesign of the mechanical coupler.

A sufficient number of new concepts were identified to derive coupling systems which represent a significant improvement over the present system.

This executive summary is the first of two volumes. Volume II, 446 pages, presents detailed documentation of the project.

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PREFACE

The work described in this report was carried out under the direction of the Transportation Systems Center of the U.S. Department of Transportation in the context of an overall project of the Federal Railroad Administration (FRA) to provide a technical basis for the improvement of rail transportation service, efficiency and productivity. The work was sponsored by the FRA Office of Research and Development, Office of Freight Systems.

The work reported here has been coordinated with the Association of American Railroads (AAR) Advanced Coupling Concepts Steering Committee. It is an element of a larger program initiated by the FRA and AAR Joint Study Group on Advanced Coupler Concepts which contains both economic and technical elements.

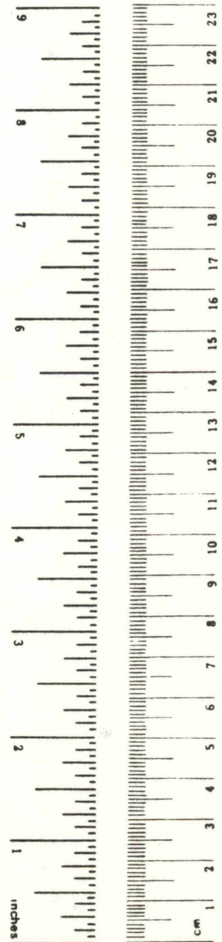
This final report is organized into two volumes. The Executive Summary (Volume I) is an easily readable summary of the project to survey and assess coupler systems for rail freight cars. The Report (Volume II) includes the full documentation and details of the project activity.

Kearney gratefully acknowledges the cooperation of the many railroads, rapid transit companies, manufacturers, research and development organizations, U.S. Patent Office, AAR Technical Center, AAR Advanced Concepts Steering Committee, and other interested parties who provided the information required to conduct a professional, objective study. We would also like to thank DOT personnel in the Transportation Systems Center and the Federal Railroad Administration for their cooperation and assistance throughout the course of the study. The authors are grateful to L. K. Kloss for his help in preparing this report.

METRIC CONVERSION FACTORS

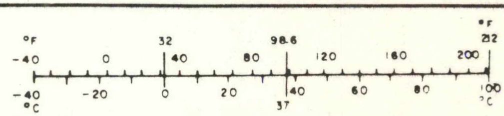
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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ABBREVIATIONS

AAR	-	Association of American Railroads
COMPENDEX	-	Engineering Index
DOT	-	U. S. Department of Transportation
EPA	-	U. S. Environmental Protection Agency
FRA	-	Federal Railroad Administration
ISMEC	-	Science and Mechanical Engineering Abstracts
NASA	-	National Aeronautics and Space Administration
NTIS	-	National Technical Information Service
ORE	-	Office for Research and Experiments
OSHA	-	Occupational Safety and Health Act (or Administration)
RPI	-	Railway Progress Institute
RRIS	-	Railroad Research Information Service
R-TRIS	-	Regional Transportation Research Information Service
TRIS	-	Transportation Research Information System
TSC	-	Transportation Systems Center
UIC	-	International Union of Railways

1. INTRODUCTION

1.1 Program Background

Under sponsorship of the Federal Railroad Administration (FRA), the Transportation System Center (TSC) of the U.S. Department of Transportation (DOT) is undertaking a research program to determine and quantify areas in which operating efficiency and productivity could be improved by changes in the present coupler systems of North American freight cars, and to define the functional requirements of coupler systems which would produce these changes.

Research and development projects have been conducted by industry suppliers and others over recent years to design various coupler systems or coupler system components. The primary thrust of the R&D effort has been for United States rapid transit application or for European rail service.

The functional concepts of these advanced systems range in sophistication from increasing the gathering range of the present coupler system to providing automatic train line air connection, and a complete redesign of the mechanical coupler. Some of these systems are in the conceptual stage; others have advanced beyond physical prototypes to actual installation.

1.2 Study Purpose

The purpose of this study is to provide an independent identification, classification, and analysis of significant freight car coupling systems concepts offering potential for improved performance and operating costs over the present system. Additionally this study represents the DOT Federal Railroad Administration's contribution to the Advanced Coupling Concepts program being carried out in cooperation with the Association of American Railroads (AAR) and the Railway Progress Institute (RPI).

To evaluate the potential of advanced coupling systems for enhancing operations, an organized review of proposed or existing advanced coupling concepts was required. The review served to identify those systems offering potential for major improvements in the current freight coupling operations.

1.3 Study Objectives

The objectives of this study were:

1) To assemble and synthesize information related to advanced coupler systems in terms of their respective functional concepts.

2) To identify, characterize, and select the most promising concepts of these systems and group them into logical combinations for candidate coupling systems which warrant further study.

3) To conduct an objective feasibility study and preliminary engineering and cost analysis of the concepts in the candidate coupling system; specifically excluded is an estimate of the benefits of implementation.

1.4 Study Scope

The scope of the study included advanced coupler concepts that have been proposed either domestically or abroad, patented or nonpatented, regardless of their respective stage of development or degree of sophistication.

The intent is that the results of this project will be combined with the economic study of advanced coupler systems presently being performed under AAR sponsorship. For this reason, particular emphasis was placed on evaluating the advanced coupler systems from the functional standpoint as they might impact railroad operational procedures, safety, and efficiency of operations.

The scope of the proposed study did not include original research or design of hardware development. The thrust of the study was to review and characterize work performed by others in advanced technology and to identify the concepts that could most readily effect improvements in the rail freight industry.

2. METHOD OF APPROACH

The basic method of approach was to make a comprehensive search as a prerequisite to establishing significant coupler concepts which would be used to formulate candidate coupling systems.

The search program consisted of a literature search, a patent search, and railroad industry interviews. A summary of these search elements follows. Volume II, Appendix D contains a full bibliography of all searches and interviews as well as cross-reference details.

2.1 Literature Search

The study team conducted an extensive search of published sources of advanced coupling concepts. This literature included railroad industry technical literature, trade publications, and journal articles extracted from 21 search topics needed to interrogate the information retrieval sources for information on railroad coupling.

A computer interrogation using these search topics was made from the six retrieval sources noted below:

1) RRIS - Railroad Research Information Service

2) NTIS - National Technical Information Service (Lockheed Aircraft)

3) ISMEC - Science Abstracts, Mechanical Engineering and Engineering Management - Part of INSPEC (Lockheed Aircraft)

4) R-TRIS - Regional Transportation Research Information Service (Transportation Center Library of Northwestern University)

5) COMPENDEX - Engineering Index (Lockheed Aircraft)

6) TRIS - Transportation Research Information System (Battelle Automated Search Information System)

For some references it was necessary to obtain additional information through the DOT library or the Library of Congress. For a few references, it was required to obtain a translation into English from the original foreign language in which the reference document was published.

2.2 Patent Search

A patent search was conducted for the purpose of identifying major concepts which might have been patented but not yet developed into an actual coupling system. Accordingly, even though they were patented, undeveloped concepts would not necessarily be reviewed in the literature or discussed during visits to the manufacturers.

The primary field of search was in the patent class 213 covering Railway Draft Appliances and subclasses within that class. Also, the most relevant secondary fields were searched, particularly class 105 covering Railway Rolling Stock and within that subclasses 2, 3, and 4.

The selection of these classes for the primary search was made in consultation with Drayton Hoffman of the U.S. Patent Office, who was primary examiner for class 213 for 18 years concluding in 1973. His experience as an examiner ensured that anything significant in the railway coupling field would be found in either of these classes under the subclasses search.

It was found in the patent search that the significant foreign concepts had all been patented in the United States, since the United States is a major railroad country. Thus, the search of the U.S. patents did, in fact, reveal patents secured by companies from foreign countries as well as patents of the U.S. companies.

2.3 Railroad Industry Interviews

The literature search provided the framework for defining the group industry coupler system suppliers or those organizations with research and development efforts leading to significant advanced coupling concepts. Representatives of 17 manufacturers were contacted. Additionally, it was felt that coupler users could provide valuable insight related to current products or products used during some testing phases; therefore, interviews included discussions with eight rapid transit and railroad organizations.

Contact was established with personnel in all organizations selected. These contacts provided a mechanism to:

1) Clarify information and complete missing data which literature did not provide.

2) Identify areas of potential improvement for present coupling systems.

3) Discuss supplier developments not intended for general freight service which might have possible freight application.

3. SURVEY RESULTS

3.1 Potential Concepts

The potential list of possible improvements in the coupling interface between freight cars is endless. At the outset of the program, an attempt was made to eliminate those potential coupler improvements which were not considered germane to the scope of work of this contract. This was done in context with the task listings in the subject contract in conjunction with technical direction from the DOT/TSC Technical Program Manager and other members of the Advanced Coupling Concepts Committee.

The primary thrust of the Literature and Patent Searches and the Railroad Industry Interviews was directed at those concepts affecting the direct interface between adjacent cars. Concepts affecting an incidental interface (e.g., electric train lines within the car system) were specifically excluded. Considerations were given, however, to such items as control techniques to be used with electric train lines.

Many elements of freight car design could be considered as being impacted by the coupler system. For purposes of definition of an advanced coupler concept system, it was determined that consideration would be given only to those portions of the freight car system which are outward from the attachment point of the coupler shank to the yoke.

Essentially, the advanced coupler system analysis did not include consideration for changes in yokes, draft gear and followers, center or side sills, cushion underframe devices, or portions of the braking system internal from the angle cock.

Likewise, detailed consideration was not given for incidental items which are considered as support items to the basic coupling system or for internal incidental parts for improved performance of the coupler system which, in and of themselves, were not relevant to the basic change in coupler capability. These include such elements as support chain for the air hose, uncoupling levers, and changes in design or strength of internal parts within the coupler head such as knuckle pins.

3.2 Significant Concepts

A review of the partial list of coupler improvements determined in the searches and interviews indicated a logical grouping of these concept ideas by functional categories. These categories involved the impact of the concepts on:

1) Improving Train Airline System
2) Improving Mechanical Coupling
3) Improving Mechanical Uncoupling
4) Improving General Train Control Systems.

All of the significant coupling concepts were identified and then categorized according to these basic functional characteristics.

As a result of the literature and patent searches and the industry interviews, 108 separate significant coupler concepts were identified. A list of the significant concepts and identification of the mechanical function category impacted by each concept is given in Volume II, Section 4 of the final report and an abstract of each significant concept is included in Volume II, Appendix B.

3.3 Conclusions

From a review of the technical data obtained in the survey, several points are evident, including:

1) In the United States, development efforts leading to patent application or published technical data on new concepts have been diminished over the last 15 years as compared to previous times.

2) The decrease in U.S. development efforts has coincided with the changing usage and profitability of the American railroads.

3) It appears that recent significant technical advancements have been patented. However, the necessary development work required for product marketing has been set aside primarily as a result of a lack of guaranteed economic market for the new concepts.

4) As discovered during interviews, it appears that no recognized industry supplier is working on any revolutionary new concepts.

5) Significant development effort has been applied in Europe over the last 25 years for the development of a standard coupler to meet the requirements of the UIC Synthesis coupler standards.

6) A great deal of the European development effort has been aimed at meeting transitionary components needed for

"mixed" couplers of the old hook and screw type as they would mate the new UIC Synthesis couplers.

7) Most of the European coupler effort has been aimed at modifications of the basic Willison coupler design which is a rigid knuckle type.

8) Most of the European development work for air or electrical connectors has been associated with their use as an integral part of the final rigid coupler design. This differs from the U.S. developments in this area which have been concentrated in the area of separate air connection devices.

A sufficient number of new coupler concepts were identified to derive coupling systems which represent a significant improvement over the present system.

4. CANDIDATE COUPLING SYSTEMS

4.1 Basic Philosophy

In order to establish the candidate coupling system, it is first necessary to define the basic philosophic goals for accomplishment by the new coupling systems. It seems reasonable to define the ultimate fully automatic coupler as any coupler system which will, without any manual assistance, couple two or more freight cars mechanically, pneumatically, and (if necessary for full system automation) electrically. Moreover, this fully automatic coupler system should maintain the coupled integrity with highest reliability through all reasonably anticipated service operating conditions.

One of the prime requisites of the fully automatic coupling system must be the ability of the two mating coupler heads to come together, without any previous manual guiding of the coupler head, in such a way that first time coupling is assured. <u>It is thus fundamental that the ultimate automatic coupling system should include provisions to preclude the possibility of a by-pass or miscoupling for any reason</u>.

4.2 Degree of Automation

It is recognized that all of the desired characteristics of a fully automatic coupler system are not currently embodied in a single new concept or system. The ultimate coupler system can be achieved only through improvements in present basic coupling subsystems or in the addition of new subsystems which give greater capability than that available with the present Type "E" coupler system.

To establish new candidate coupling systems, three basic subsystem areas were defined: coupling and uncoupling capability, air connection and brake valve system control, and full train line electrical systems and controls. The extent of the overall coupling system improvement will be a function of the degree of automation brought about by improvements to individual concepts as they are applied to each of the subsystems noted above.

None of the candidate coupling systems contain all the potential degrees of improvement or automation possible in light of current technology. Each of the candidate coupling systems noted below, however, when taken through the suggested change steps do represent a potential for achieving a fully automated coupler system which approaches the ultimate desired system.

4.3 Preliminary Candidate Coupling Systems

Three different coupling design concepts were established as the basic coupling approaches on which to build three candidate coupling systems. These three basic coupling concepts are:

1) Free knuckle type coupler, which is fully compatible with (and a modification of) the present Type "E" coupler system.

2) Semirigid, spread-claw design, which is not compatible with the present Type "E" system, but which represents the best of the concepts utilized in the UIC European synthesis freight car coupler designs and in the majority of mine car applications.

3) Rigid, flat-faced, horn-funnel design, which is not compatible with the present Type "E" coupler system but which represents the best design features of most current rapid transit systems and some passenger service applications.

The realization of the potential for the full candidate coupling system is achieved through major change steps. These changes are based on a logical increase in system capability and degree of automation. In addition, the change steps take into consideration the system operating problems which would be involved in the retrofit program associated with these changes.

4.4 Summary of Capabilities of Candidate Coupling Systems

The detailed listing of capabilities, advantages, and disadvantages of each candidate coupling system is included in Volume II, Section 5 of the final report. A brief summary of the capabilities of each system follows.

1) System 1 (Compatible "Free Knuckle" System). See Tables 1 through 4.

(a) Has the primary advantage of being totally compatible with all freight cars currently in U.S. rail-freight system. The primary capabilities of the basic System 1-1A and 1-1B include increased gathering range, knuckle open capability, and coupler entrapment and interlock features, thus overcoming the major deficiencies in the present Type "E" system.

(b) System Change 1-2 adds the automatic air connection and automatic brake valve control as a mechanical function of the coupling and uncoupling processes. These features overcome the most critical safety needs relating to the necessity of trainman going between cars to complete the air connecting system or to prepare cars for proper coupling.

(c) System Change 1-3 adds the capability of remote control by the additional electropneumatic and electronic control systems. This latter feature embodies the long-range potential for complete sensing and control of train operations from the locomotive or from some external control point. This system is limited to approximately six to eight electrical contacts in the automatic electrical connector.

2) System 2 (Noncompatible, Semirigid, Spread-Claw, Hinged Hook System). See Tables 5 and 6.

(a) The primary advantages in this system are the very wide gathering range which it offers, a rugged and proven system and "knuckle open" capability. The basic System 2-1 includes an integral air connection coupling which is protected within the face of the gathering claws of the coupler. This protection feature is the best of the three systems in that it offers significant mechanical and environmental protection to the automatic air connection face. Since the automatic air connector unit represents a most significant and critical feature in the train operating sequence, candidate System 2 offers a particular and unique advantage in this respect.

(b) System Change 2-2, similar to System Change 1-3, is limited to approximately 6 to 8 electrical contacts which can be readily added to the system for the final step involving electrical sensing and control circuits.

3) System 3 (Noncompatible, Rigid, Flat-Face, Hinged Hook/Funnel System). See Tables 7 and 8.

(a) The basic coupler System 3-1 contains the unique advantage of being a totally rigid system which gives an exceptionally stable platform for attaching air or electrical connectors. This advantage is accompanied by the disadvantage of a heavy coupler unit, which requires a significant amount of machining to achieve the slack-free characteristic and which likewise requires a critical positioning control in order to prevent oblique coupling forces from damaging the coupler head faces. The primary advantages of the basic system are its increased gathering range, "knuckle open" capability, rigid interlocking of mated couplers, and an integral air connection system.

(b) System Change 3-2 adds the capability for a large number (50 to 100) of electrical contacts as a part of an electro-pneumatic control system.

A detailed listing of concepts contained in each coupling system is given in Tables 1 through 8.

The format for presentation of the three candidate systems is as follows:

1) Compatible System #1
   - (a) Basic System 1-1A, Short Car
   - (b) Basic System 1-1B, Long Car
   - (c) System Change 1-2, Addition of Air Connector

TABLE 1.-CANDIDATE COUPLING SYSTEMS - COMPATIBLE SYSTEM NUMBER 1-1A (BASIC SHORT CAR SYSTEM)

OPERATIONAL CHARACTERISTIC WITHIN THE OVERALL COUPLING SYSTEM	CONCEPT DESCRIPTION	ESTIMATED QUANTITATIVE VALUES OF IMPROVEMENT
IMPROVE MECHANICAL COUPLING		
Automatic Engagement		
Lateral Gathering Range	. Coupler knuckle contour change.	6.875" (1.7 x standard)
Vertical Gathering Range	. Guard arm extension faces on top and bottom shelves.	Approximately 6" (2 x standard)
Positive Locking	. Compatimatic* coupler head (positive mechanical rotation of lockset by force of mating coupler head).	
Positive Retainment		
Wider Coupler Speed Range	. Compatimatic* coupler head with mechanical forced unlocking.	
Reduced Free Slack	. Revise front shape of knuckle (add 5/64" to front face).	0.625" (0.8 x standard)
Vertical Interlock and Broken Coupler Entrapment	. Top and bottom coupler shelf (self-interlocking to prevent both top and bottom slip-over).	
Location Control		
Self Centering	. Self centering draft gear/shank design (draft gear compression forces act to bias shank laterally).	± 2" (0.6 x standard)
Reduced Maintenance	. Lubrication fittings at coupler head and shank wear points.	
IMPROVE MECHANICAL UNCOUPLING		
Recoupling Capability		
Knuckle Always Open	. Compatimatic* coupler head (knuckle is spring loaded in open position when uncoupled).	
IMPROVE GENERAL SYSTESM		
Operational Safety	. Blunt and round front edges of coupler and shelves (reduced possibility of rupture of tank car in derailment situation).	Estimated 60% reduction of rupture probability
ADAPTER TO MAKE COMPATIBLE WITH AAR TYPE "E" SYSTEM	. Not required.	
	Note: (*) Developed by National Castings Division, Midland Ross Corporation.	

TABLE 2.-CANDIDATE COUPLING SYSTEMS - COMPATIBLE SYSTEM NUMBER 1-1B (BASIC LONG CAR SYSTEM)

OPERATIONAL CHARACTERISTIC WITHIN THE OVERALL COUPLING SYSTEM	CONCEPT DESCRIPTION	ESTIMATED QUANTITATIVE VALUES OF IMPROVEMENT
IMPROVE MECHANICAL COUPLING		
Automatic Engagement		
Lateral Gathering Range	. Coupler knuckle contour change.	6.875" (1.7 x standard)
Vertical Gathering Range	. Type "F" interlocking coupler head.	4.5" (1.5 x standard)
Positive Locking	. Compatimatic* coupler head (positive mechanical rotation of lockset by force of mating coupler head).	
Positive Retainment		
Wider Coupler Speed Range	. Compatimatic* coupler head (with mechanical forced unlocking).	
Reduced Free Slack	. Revise front shape of knuckle (add 5/64" to front face).	Approximately 0.3" (0.4 x standard)
Vertical Interlock and Broken Coupler Entrapment	. Type "F" interlocking coupler head (interlocking arm pocket). . Top coupler shelf (to prevent top slipover of type "E" mated coupler).	
Location Control		
Reduced Contour Angling	. Type "F" interlocking coupler head.	Lateral = 3.75^{o} rocking Vertical = 2^{o} rocking, 0.125" sliding
Automatic Positioning	. Hydraulic, direct guided coupler positioning device. . Vertical spring carrier system.	Eliminate estimated 90% of bypasses
Reduced Maintenance	. Lubrication fittings at coupler head and shank wear points.	
	Note: (*) Developed by National Castings Division, Midland Ross Corporation.	

TABLE 2.-CANDIDATE COUPLING SYSTEMS - COMPATIBLE SYSTEM NUMBER 1-1B (CONTINUED)

OPERATIONAL CHARACTERISTIC WITHIN THE OVERALL COUPLING SYSTEM	CONCEPT DESCRIPTION	ESTIMATED QUANTITATIVE VALUES OF IMPROVEMENT
IMPROVE MECHANICAL UNCOUPLING		
<u>Recoupling Capability</u>		
Knuckle Always Open	. Compatimatic* coupler head (positive mechanical rotation of position when uncoupled).	
IMPROVE GENERAL SYSTEMS		
<u>Operational Safety</u>	. Blunt and round front edges of coupler and top shelf (reduced possibility of rupture of tank car in derailment situation).	Estimated 60% reduction of rupture probability
ADAPTER TO MAKE COMPATIBLE WITH AAR TYPE "E" SYSTEM	. Not required.	
	Note: (*) Developed by National Castings Division, Midland Ross Corporation.	

TABLE 3.-CANDIDATE COUPLING SYSTEMS - COMPATIBLE SYSTEM NUMBER 1-2 (ADDITION OF AIR CONNECTION AND VALVE CONTROL SYSTEM)

OPERATIONAL CHARACTERISTIC WITHIN THE OVERALL COUPLING SYSTEM	CONCEPT DESCRIPTION	ESTIMATED QUANTITATIVE VALUES OF IMPROVEMENT
IMPROVE TRAIN AIR LINE SYSTEM		
Automatic Control		
Automatic Air Connection	. Automatic air connection system with horizontal articulation capability.	Lateral = 5" Vertical = 4" Angular = 7^{o}
Automatic Air Valve Control	. Automatic mechanical air valve operation (mechanical push rod in face of air connector initiates valve action).	
Improved Performance		
Air Seal Leak Rates, Hose Reliability and Reduced Maintenance	. Automatic air connection system.	
IMPROVE MECHANICAL UNCOUPLING		
Uncoupling Capability		
Push Button Release	. Remote uncoupling button at side of car (opens air valve). . Hydraulic uncoupling operating mechanism (direct pneumatic operation of standard uncoupling linkage).	
IMPROVE GENERAL SYSTEMS		
Automatic Train Brake Control	. Provide for nonbraking (retention of air) after intentional uncoupling. . Provide for emergency braking after unintentional uncoupling (immediate release of air). (Operation of uncoupling lever initiates valve action.)	
ADAPTER TO MAKE COMPATIBLE WITH AAR TYPE "E" SYSTEM	. Air hose/glad hand connection capability retained (on opposite side of coupler head) - no other adapter required.	

TABLE 4.-CANDIDATE COUPLING SYSTEMS - COMPATIBLE SYSTEM NUMBER 1-3 (ADDITION OF ELECTRO-PNEUMATIC CONTROL SYSTEM)

OPERATIONAL CHARACTERISTIC WITHIN THE OVERALL COUPLING SYSTEM	CONCEPT DESCRIPTION	ESTIMATED QUANTITATIVE VALUES OF IMPROVEMENT
IMPROVE MECHANICAL COUPLING		
Location Control	. Automatic disengagement of centering/positioning device at coupling and engagement at uncoupling (electro-pneumatic engagement of positioning device 31b).	
IMPROVE MECHANICAL UNCOUPLING		
Uncoupling Capability	. Electro-pneumatic control system to initiate uncoupling from electric signal within train to operate pneumatic uncoupling mechanism Number 943).	
IMPROVE GENERAL SYSTEMS		
Automatic Train Brake Control	. Provide time delay set provisions for brakes after intentional uncoupling (from electrical signal to timing delay system in pneumatic uncoupling control 245).	
Electrical Train Line System	. Add electrical connector system (rigid attached at bottom of air connector). . Air piston sequencing of contractors after mechanical connection. . Up to 6-8 circuits of butt face, spring loaded, rotating type. . Utilize silver plated or silver button tipped contactors. . Provide mechanical hand back-up contactor engagement. . Provide maintenance removal potential for mated contactors. . Provide environmental cover with opening by pneumatic sequencing after mechanical mating (initiated by coupling push rod). . Provide nylon hinges for environmental cover. . Provide plastic insulators over environmental cover. . Provide rubber environmental sealing gasket at edge of contactor block.	
Sensing and Control System	. Electro-pneumatic servo control system at each coupler. . Electronic, solid state multiplexing sending and control system (master system in locomotive and logic system in car). . Optional microwave receiving and control system in locomotive.	
ADAPTER TO MAKE COMPATIBLE WITH AAR TYPE "E" SYSTEM	. Not required.	

TABLE 5.-CANDIDATE COUPLING SYSTEMS - NONCOMPATIBLE SYSTEM NUMBER 2-1 (SEMIRIGID, SPREAD CLAW, BASIC SYSTEM)

OPERATIONAL CHARACTERISTIC WITHIN THE OVERALL COUPLING SYSTEM	CONCEPT DESCRIPTION	ESTIMATED QUANTITATIVE VALUES OF IMPROVEMENT
IMPROVE TRAIN AIR LINE SYSTEM		
<u>Automatic Control</u>		
Automatic Air Connection	. Spring loaded integral air connection. . Double concentric compressible rubber seals.	
Automatic Air Valve Control	. Automatic mechanical air valve operation (mechanical push rod in face of coupler head initiates valve action).	
<u>Improved Performance</u>		
Air Seal Leak Rates and Hose Reliability	. Automatic air connection system.	
Reduced Maintenance	. Pivoted rear removal of air connection assembly.	
IMPROVE MECHANICAL COUPLING		
<u>Automatic Engagement</u>		
Improve Lateral and Vertical Gathering Ranges	. Spread claw gathering of semirigid coupler head.	$\pm$ 8.7" (4.3 x standard) lateral $\pm$ 5.5" (3.7 x standard) vertical
Positive Locking	. Spring loaded locking hook with spring energized locking mechanism.	
<u>Positive Retainment</u>		
Wider Coupling Speed Range	. Spring loaded locking hook (positive snap lock at coupling).	
Reduced Free Slack	. Cast/forged coupler head with machined seating faces.	
Vertical Interlock and Broken Coupler Entrapment	. Interlocking gathering claws and locked mated hooks.	0.3" (0.4 x standard)
<u>Location Control</u>		
Self Centering	. O.R.E. II cross beam support centering device. . Vertical spring carrier system.	$\pm$ 1.2" (0.34 x standard)
Reduced Contour Angling	. Semirigid coupler head with interlocking claws.	
<u>Reduced Maintenance</u>	. Lubrication fittings at coupler head and shank wear points.	

TABLE 5.-CANDIDATE COUPLING SYSTEMS - NONCOMPATIBLE SYSTEM NUMBER 2-1 (CONTINUED)

OPERATIONAL CHARACTERISTIC WITHIN THE OVERALL COUPLING SYSTEM	CONCEPT DESCRIPTION	ESTIMATED QUANTITATIVE VALUES OF IMPROVEMENT
IMPROVE MECHANICAL UNCOUPLING		
Uncoupling Capability		
Alternate Side Lever, or	. Second uncoupling lever with cable connection.	
Push Button Release	. Remote uncoupling button at side of car (to operate air valve in coupler head for uncoupling release).	
In Draft	. Air cylinder release of rotary locking block in coupler head (provides force boost for uncoupling in draft).	Up to 8,000 pounds draft force
Recoupling Capability		
Knuckle Always Open	. Spring loaded locking pawl (spring cocked at unloading).	
Prevent Recoupling	. Manual lock open of locking pawls to prevent locking (to allow yard movement without automatic coupling lock).	
IMPROVE GENERAL SYSTEMS		
Automatic Train Brake Control	. Provide for nonbraking (retention of air) after intentional uncoupling.	
	. Provide for emergency braking after unintentional uncoupling (immediate release of air). (Operation of uncoupling lever initiates valve action.)	
ADAPTED TO MAKE COMPATIBLE WITH AAR TYPE "E" SYSTEM	. Air hose/glad hand adapter (plus) coupler head adapter kit is required.	

TABLE 6.-CANDIDATE COUPLING SYSTEMS - NONCOMPATIBLE SYSTEM NUMBER 2-2 (ADDITION OF ELECTRO-PNEUMATIC CONTROL SYSTEM)

OPERATIONAL CHARACTERISTIC WITHIN THE OVERALL COUPLING SYSTEM	CONCEPT DESCRIPTION	ESTIMATED QUANTITATIVE VALUES OF IMPROVEMENT
IMPROVE MECHANICAL COUPLING		
Location Control	. Automatic disengagement of centering at coupling and engagement at uncoupling (electro-pneumatic engagement of centering device 318).	
IMPROVE MECHANICAL UNCOUPLING		
Uncoupling Capability	. Electro-pneumatic control system to initiate uncoupling from electrical signal within train (to operate pneumatic uncoupling mechanism 391).	
IMPROVE GENERAL SYSTEMS		
Automatic Train Brake Control	. Provide time delay set provisions for brakes after intentional uncoupling (from electrical signal to timing delay system in pneumatic uncoupling control 254).	
Electrical Train Line System	. Add electrical connector integral to coupler head.	
	. Air piston sequencing of contactors after mechanical connection.	
	. Up to 6-8 circuits of butt face, spring loaded rotating type.	
	. Utilize silver plated or silver button tipped contactors.	
	. Provide mechanical hand back-up contactor engagement.	
	. Provide maintenance removal potential for mated contactors.	
	. Provide environmental cover with opening by pneumatic sequence after mechanical mating (initiated by coupling push rod).	
	. Provide nylon hinges for environmental cover.	
	. Provide plastic insulators over environmental cover.	
	. Provide rubber environmental sealing gasket at edge of contactor block.	

TABLE 6.-CANDIDATE COUPLING SYSTEMS - NONCOMPATIBLE SYSTEM NUMBER 2-2 (CONTINUED)

OPERATIONAL CHARACTERISTIC WITHIN THE OVERALL COUPLING SYSTEM	CONCEPT DESCRIPTION	ESTIMATED QUANTITATIVE VALUES OF IMPROVEMENT
IMPROVE GENERAL SYSTEMS (CONTINUED)		
<u>Sensing and Control System</u>	. Electro-pneumatic servo control system at each coupler.	
	. Electronic, solid state multiplexing sensing and control system (master system in locomotive and logic system in car).	
	. Optional microwave receiving and control system in locomotive.	
ADAPTER TO MAKE COMPATIBLE WITH AAR TYPE "E" SYSTEM	. No additional adapters required.	

TABLE 7.-CANDIDATE COUPLING SYSTEMS - NONCOMPATIBLE SYSTEM NUMBER 3-1 (RIGID, FLAT FACE, BASIC SYSTEM)

OPERATIONAL CHARACTERISTIC WITHIN THE OVERALL COUPLING SYSTEM	CONCEPT DESCRIPTION	ESTIMATED QUANTITATIVE VALUES OF IMPROVEMENT
IMPROVE TRAIN AIR LINE SYSTEM		
Automatic Control		
Automatic Air Connection	. Spring loaded, compressible rubber, integral air connector.	
Automatic Air Valve Control	. Automatic mechanical air valve operation. (Mechanical push rod in face of coupler head initiates valve action.)	
Improved Performance		
Air Seal Leak Rates, Hose Reliability and Reduced Maintenance	. Automatic air connection system.	
IMPROVE MECHANICAL COUPLING		
Automatic Engagement		
Improve Lateral and Vertical Gathering Ranges	. Horn/funnel gathering of rigid coupler head.	± 5" (2.5 x standard) lateral ± 5" (3.3 x standard) vertical
Positive Locking	. Spring loaded locking hook and direct locking catch (from compression of guide pins on coupler face).	
Positive Retainment		
Wider Coupling Speed Range	. Spring loaded locking hook (positive interlock at coupling).	
Reduced Free Slack	. Machined flat mating front faces and locking detents.	Zero free slack (design nominal)
Vertical Interlock and Broken Coupler Entrapment	. Interlocking horns with locked hooks and aligning pin/dowel interlock.	
Location Control		
Reduced Contour Angling	. Rigid coupler heads with interlock.	
Automatic Positioning	. Hydraulic, direct guided coupler positioning device. . Vertical spring carrier system.	
Reduced Maintenance	. Lubrication fittings at coupler head and shank wear points.	

TABLE 7.–CANDIDATE COUPLING SYSTEMS – NONCOMPATIBLE SYSTEM NUMBER 3-1 (CONTINUED)

OPERATIONAL CHARACTERISTIC WITHIN THE OVERALL COUPLING SYSTEM	CONCEPT DESCRIPTION	ESTIMATED QUANTITATIVE VALUES OF IMPROVEMENT
IMPROVE MECHANICAL UNCOUPLING		
Uncoupling Capability		
Push Button Release	. Remote uncoupling button at side of car (to operate self-contained pneumatic uncoupling release).	
In Draft	. Locking hooks forced apart by cam wedge force (from pneumatic cylinder through rotary locking block) to provide force boost for uncoupling in draft.	Up to 8,000 pounds draft force
Recoupling Capability		
Knuckle Always Open	. Spring loaded locking hook (set ready at uncoupling).	
IMPROVE GENERAL SYSTEMS		
Automatic Train Brake Control	. Provide for nonbraking (retention of air) after intentional uncoupling. . Provide for emergency braking after unintentional uncoupling (immediate release of air) (operation of uncoupling lever initiates valve action).	
ADAPTER TO MAKE COMPATIBLE WITH AAR TYPE "E" SYSTEM	. Air hose/glad hand adapter (plus) coupler head adapter unit is required.	

TABLE 8.-CANDIDATE COUPLING SYSTEMS - NONCOMPATIBLE SYSTEM NUMBER 3-2 (ADDITION OF ELECTRO-PNEUMATIC CONTROL SYSTEM)

OPERATIONAL CHARACTERISTIC WITHIN THE OVERALL COUPLING SYSTEM	CONCEPT DESCRIPTION	ESTIMATED QUANTITATIVE VALUES OF IMPROVEMENT
IMPROVE MECHANICAL COUPLING		
Location Control	. Automatic disengagement of centering/positioning device at coupling and engagement at uncoupling (electro-pneumatic engagement of positioning device 31b).	
IMPROVE MECHANICAL UNCOUPLING		
Uncoupling Capability	. Electro-pneumatic control system to initiate uncoupling from electrical signal within train (to operate pneumatic uncoupling mechanism 9,391).	
IMPROVE GENERAL SYSTEMS		
Automatic Train Brake Control	. Provide time delay set provisions for brakes after intentional uncoupling (from electrical signal to timing delay system in pneumatic uncoupling control 254).	
Electrical Train Line System	. Add electrical connection box below face of coupler head. . Air piston sequencing of contactors after mechanical connection. . From 50-100 circuits of butt face, spring loaded, rotating type. . Utilize silver plated or silver button tipped contactors. . Provide mechanical hand back-up contactor engagement. . Provide maintenance removal potential for mated contactors. . Provide environmental cover with opening by pneumatic sequencing after mechanical mating (initiated by coupling push rod). . Provide nylon hinges for environmental cover. . Provide plastic insulators over environmental cover. . Provide rubber environmental sealing gasket at edge of contactor block.	
Sensing and Control System	. Electro-pneumatic servo control system at each coupler. . Electronic, solid state multiplexing sensing and control system (master system in locomotive and logic system in car). . Optional microwave receiving and control system in locomotive.	
ADAPTER TO MAKE COMPATIBLE WITH AAR TYPE "E" SYSTEM	. No additional adaptors required.	

and Valve Control System

(d) System Change 1-3, Addition of Electropneumatic Control Systems

2) Noncompatible System #2, Semirigid, Spread-Claw

(a) Basic System 2-1

(b) System Change 2-2, Addition of Electropneumatic Control Systems

3) Noncompatible System #3, Rigid, Flat-Faced

(a) Basic System 3-1

(b) System Change 3-2, Addition of Electropneumatic Control Systems

5. PRELIMINARY COSTING

5.1 Introduction

Each of the Candidate Coupling Systems was subjected to a preliminary engineering evaluation as related to costing. This evaluation was directed at determination of a reasonable estimate for the cost of each of the separate subsystem elements.

The preliminary costs for each system element were derived by using a combination of the following inputs:

1) Review of technical literature for past cost estimates.

2) Discussions with railroad industry suppliers and users for verification of concept production potentials.

3) Preliminary engineering evaluation of complexity of new concepts as compared with the basic Type "E" system.

4) Evaluation of present costing as a function of the complexity of concept design and relative quantities produced.

5) Engineering estimate of potential replacement life of new concepts as compared to reported field problems with similar systems.

5.2 General Limitations

Several assumptions were made for both technical and cost aspects as applicable to the various subsystem elements. These assumptions were made to more adequately define or constrain the possible variations in the preliminary cost estimates. These constraints are:

5.2.1 Cost Constraints

1) All costs are based on constant 1975 dollars and include an estimate of the total of labor and material costs.

2) Projections of costs assume that full quantity production would be made at a level of at least 50,000 car sets per year.

3) Costs are estimated as an "order of merit" based on a preliminary understanding of the potential for a final design. As such, the cost estimates are believed consistent in the costing approach but should be considered to have an uncertainty level for any specific item of $\pm$ 25 percent.

4) No calculation was made for estimated inventory costs, since these are subject to unique control by each railroad.

5) Annual maintenance and replacement costs were estimated on the basis of the estimated replacement life of each listed equipment item including estimated replacement and maintenance labor.

6) No costs were included for preparation or repair of old cars prior to installation of the new coupler system (or subsystem). It is assumed that all cars to be modified would be in a state of full repair at the time of coupler modifications.

Significant design work has been accomplished by European railroads to determine the potential costs for both car preparation and coupler changeover. One reference included an estimate of approximately $1,100 for the average cost for preparation of old cars to insure an adequate anchoring and sill strength for mounting of new center-buffer coupler units. No technical data were available to allow a reasonable basis for estimating a comparable preparation cost for an "average" U.S. rail car.

7) It is assumed that an average of one Interchange Adapter unit would be required for each car which would have a system 2 or 3 coupler.

8) Initial system costs for a new car system are estimated as additional to the cost for the basic car equipped with the standard coupler and draft gear system. If the new system element is not estimated to increase the cost over the basic car system, this estimate is indicated by a "N.I." notation (for NO INCREASE).

9) Initial system costs for modified cars are estimated as an addition to the cost for a new basic coupler and draft gear system.

10) No cost estimate is included for the value of the revenue time loss by each car during the coupler modification program.

11) No costs are included for any peripheral safety or back-up equipment which might be designated by AAR or Government agencies as required to be used in conjunction with any new coupler system.

5.2.2 Technical Constraints

1) It is assumed that the maximum utilization would be obtained from casting as opposed to welding or machining. In particular, this applies to shelves or guard-arm extensions which are assumed to be manufactured as a one-piece casting as compared to weldment additions to the basic coupler heads.

2) Grade "C" steel is assumed as the standard for coupler castings.

3) It is assumed that the AAR rules would be modified to allow tapping into the main air system to attain pressure for operation of valves and force boosting of uncoupling and valve operation. Cost estimates have been included in Subsystems 1-2, 2-1, and 3-1 for the check valves and holding reservoirs necessary to safely accomplish this operation.

5.3 Preliminary Cost Estimates

Included in Tables 9 through 11 is a summary of the individual preliminary cost estimates for each of the separate candidate coupler subsystems.

The tables list a summary of the three cost estimates for each of the three candidate coupling systems as applicable to an "average" car. The system cost summaries are compared by cumulating the increased costs from three primary subsystem groupings that are associated with increasing automation and improving operational characteristics. The groupings are:

1) Improvements in mechanical coupling and uncoupling.

2) Improvements for automatic air connection and valve control.

3) Improvements for full electropneumatic control.

6. DEVELOPMENT RECOMMENDATIONS

6.1 Development Plan

The most fundamental decision must be that of choosing between a fully compatible system (System 1) and a noncompatible system (Systems 2 or 3). This decision must be based on an

TABLE 9.-SUMMARY OF COST ESTIMATES(1) FOR CANDIDATE COUPLING SYSTEMS INSTALLED ON AN "AVERAGE"(2) NEW CAR

PRIMARY IMPROVEMENTS ACCOMPLISHED BY CANDIDATE COUPLING SYSTEMS	SYSTEM 1 - TOTALLY COMPATIBLE WITH "E" SYSTEM		SYSTEM 2 - NONCOMPATIBLE SEMIRIGID, SPREAD CLAW SYSTEM		SYSTEM 3 - NONCOMPATIBLE RIGID, FLAT FACED SYSTEM	
	SUBSYSTEM COST, DOLLARS(1)	CUMULATIVE SYSTEM COST, DOLLARS(1)(3)	SUBSYSTEM COST, DOLLARS(1)	CUMULATIVE SYSTEM COST, DOLLARS(1)(3)	SUBSYSTEM COST, DOLLARS(1)	CUMULATIVE SYSTEM COST, DOLLARS(1)(3)
1. Mechanical Coupling and Uncoupling: Increase Gathering Range "Knuckle" Always Open Coupler Interlock and Entrapment Centering/Positioning of Coupler Reduced Free Slack	338	-	1 and 2 are combined into one system	-	1 and 2 are combined into one system	-
2. Automatic Air Connection and Valve Control: Automatic Air Connection with Coupling Automatic Mechanical Air Valve Operation Push Button Uncoupling from Side of Car Automatic Train Brake Control at Uncoupling	1,990	2,328	2,265	2,265	4,460	4,460
3. Full Electro-Pneumatic Control: Automatic Disengagement of Positioning at Coupling Remote Uncoupling Capability Time Delay Brake Setting at Uncoupling Automatic Electrical Connection at Coupling Train Condition Sensing Capability Multiplexing Control from Locomotive	4,800	6,528	4,900	6,565	5,575	9,435

Notes: (1) All costs are estimated based on constant 1975 dollars.
(2) "Average" car assumes a mix of 95% short cars and 5% long cars.
(3) Cumulative system costs assume that all modifications would be done simultaneously and include reductions for some redundant subsystems.

TABLE 10.-SUMMARY OF COST ESTIMATES(1) FOR CANDIDATE COUPLING SYSTEMS INSTALLED AS A MODIFICATION TO AN "AVERAGE"(2) CAR

PRIMARY IMPROVEMENTS ACCOMPLISHED BY CANDIDATE COUPLING SYSTEMS	SYSTEM 1 - TOTALLY COMPATIBLE WITH "E" SYSTEM		SYSTEM 2 - NONCOMPATIBLE SEMIRIGID, SPREAD CLAW SYSTEM		SYSTEM 3 - NONCOMPATIBLE RIGID, FLAT FACED SYSTEM	
	SUBSYSTEM COST, DOLLARS(1)	CUMULATIVE SYSTEM COST, DOLLARS(1)(3)	SUBSYSTEM COST, DOLLARS(1)	CUMULATIVE SYSTEM COST, DOLLARS(1)(3)	SUBSYSTEM COST, DOLLARS(1)	CUMULATIVE SYSTEM COST, DOLLARS(1)(3)
1. Mechanical Coupling and Uncoupling: Increase Gathering Range "Knuckle" Always Open Coupler Interlock and Entrapment Centering/Positioning of Coupler Reduced Free Slack	398	-	1 and 2 are combined into one system	-	1 and 2 are combined into one system	-
2. Automatic Air Connection and Valve Control: Automatic Air Connection with Coupling Automatic Mechanical Air Valve Operation Push Button Uncoupling from Side of Car Automatic Train Brake Control at Uncoupling	2,490	2,888	2,730	2,730	4,930	4,930
3. Full Electro-Pneumatic Control: Automatic Disengagement of Positioning at Coupling Remote Uncoupling Capability Time Delay Brake Setting at Uncoupling Automatic Electrical Connection at Coupling Train Condition Sensing Capability Multiplexing Control from Locomotive	5,375	7,663	5,475	7,605	6,225	10,555

Notes:
(1) All costs are estimated based on constant 1975 dollars.
(2) "Average" car assumes a mix of 95% short cars and 5% long cars.
(3) Cumulative system costs assume that all modifications would be done simultaneously and include reductions for some redundant subsystems.

TABLE 11.-SUMMARY OF COST ESTIMATES(1) FOR CONTINUING ANNUAL MAINTENANCE OF CANDIDATE COUPLING SYSTEMS INSTALLED ON AN "AVERAGE"(2) CAR

PRIMARY IMPROVEMENTS ACCOMPLISHED BY CANDIDATE COUPLING SYSTEMS	SYSTEM 1 - TOTALLY COMPATIBLE WITH "E" SYSTEM		SYSTEM 2 - NONCOMPATIBLE SEMIRIGID, SPREAD CLAW SYSTEM		SYSTEM 3 - NONCOMPATIBLE RIGID, FLAT FACED SYSTEM	
	SUBSYSTEM COST, DOLLARS(1)	CUMULATIVE SYSTEM COST, DOLLARS(1)(3)	SUBSYSTEM COST, DOLLARS(1)	CUMULATIVE SYSTEM COST, DOLLARS(1)(3)	SUBSYSTEM COST, DOLLARS(1)	CUMULATIVE SYSTEM COST, DOLLARS(1)(3)
1. Mechanical Coupling and Uncoupling: Increase Gathering Range "Knuckle" Always Open Coupler Interlock and Entrapment Centering/Positioning of Coupler Reduced Free Slack	52	-	1 and 2 are combined into one system	-	1 and 2 are combined into system	-
2. Automatic Air Connection and Valve Control: Automatic Air Connection with Coupling Automatic Mechanical Air Valve Operation Push Button Uncoupling from Side of Car Automatic Train Brake Control at Uncoupling	230	282	245	245	460	460
3. Full Electro-Pneumatic Control: Automatic Disengagement of Positioning at Coupling Remote Uncoupling Capability Time Delay Brake Setting at Uncoupling Automatic Electrical Connection at Coupling Train Condition Sensing Capability Multiplexing Control from Locomotive	910	1,122	750	935	1,045	1,445

Notes: (1) All costs are estimated based on constant 1975 dollars.
(2) "Average" car assumes a mix of 95% short cars and 5% long cars.
(3) Cumulative system costs assume that all modifications would be done simultaneously and include reductions for some redundant subsystems.

analysis of rail freight operations as impacted by the various elements of each system. The listed system advantages and capabilities should be adapted into the operating model to determine the potential economic savings and/or safety improvements expected to accrue from each concept. The total of these potential savings and the imputed value of safety improvements could then be equated against the estimated system costs.

6.1.1 Electropneumatic Control System

The basic operational model analysis will determine if the potential advantages of the full electropneumatic system outweigh the cost and complexity disadvantages. The next decision relates to the amount of sensing which might be required in the ultimate system.

If only a few sensing signals are desired, the smaller number of circuits in Systems 1-3 or 2-2 would be adequate. If a large number of circuits is desired, the capabilities of System 3-2 are superior.

If the lesser number of electrical contacts is determined to be acceptable, either Systems 1 or 2 are preferred from a cost standpoint. The choice between these two must be made almost solely on the basis of the relative importance of the two factors:

1) System 1 - advantage of total compatibility with the present system coupler with no coupler head interchange adapter required during any changeover process.

2) System 2 - advantage of greater strength and ruggedness, built-in mechanical protection for air and electrical connectors, and larger natural gathering range.

6.1.2 Specific System Considerations

In the engineering analysis effort conducted during this study, several areas were noted which should be listed for specific consideration. The most important of these are the following.

1) Add-On Air Connector: Subsystem 1-1A proposes the use of a modified Type "E" coupler with a top and bottom shelf as opposed to Subsystem 1-1B which proposes the use of a modified Type "F" coupler with a top shelf. This combination represents the best possible situation for obtaining the desired operational improvements with the least costly overall system.

The single deterrent to the proposed systems may be the ability of a single air connector system to operate effectively with both coupler systems. The cost advantages to the proposed systems are so great that every effort should be extended to achieve a successful development of the one "universal" air connector system. Some changes in basic specifications may be required in order to achieve this end.

2) Centering and Positioning: The addition of centering and/or positioning devices adds a significant cost to each coupler system as noted in the costs for Subsystems 1-1B, 2-1 and 3-1. These devices, however, offer the potential for a significant decrease in coupler bypasses with an associated increase in operating safety and decrease in maintenance costs.

It has been estimated that positioning devices on long cars would decrease bypasses by 80 to 90 percent. By increasing the coupler lateral gathering range, the decrease should be even greater. Railroad users have noted an "average" cost of $800 to repair a car end every 4 to 5 years solely as the result of bypass damage. Thus, the addition of positioning devices (and coupler gathering range increases) has the potential for saving \$140-\$150 per year per car in addition to increasing operational safety.

3) Environmental Covers: The use of an environmental protective cover over the electrical connectors has been set aside for a separate cost estimate for Subsystems 1-3, 2-2, and 3-2. The use of such a cover is a controversial topic in the railroad technical community. The majority opinion seems to be opposed to the covers as offering an unnecessary environmental protection while adding an expensive and highly unreliable component.

4) General Considerations: The development program directed toward improvement in the coupler system should include a secondary study relating to the impact on rail car trucks and other rail car components. In addition, a separate study should be made for train-coupler dynamics as relating to application of any of the candidate coupling systems.

6.2 Time Schedule

Considering the rudimentary state of the proposed candidate coupling systems, it is not feasible to project realistic time or cost schedules for either the development or field implementation stages. Given below, however, are some concepts and background concerning the potential time schedules and implementation plan.

6.2.1 Development and Evaluation

The complete development cycle, up to the point of being ready to start changeover to new coupler systems, may well be of 10 to 12 years duration. This cycle might generally be composed of the following elements and ranges of anticipated completion times:

1) Finalization of design concepts - 1 to 1-1/2 years.

2) Establishment of basic design specifications in keeping with AAR and governmental standards - 1/2 to 1-1/2 years.

3) Completion of hardware development as required to meet final specifications - 1 to 2 years.

4) Production of acceptable pilot test units by hardware suppliers - 1/2 year.

5) AAR qualification test program for competing supplier units - 2 to 4 years. (Earlier engineering prototype tests conducted in the mid 30's by the AAR required 4 years for testing and tabulation of the data.)

6) Field testing in various railroad environments as required to "debug" final hardware designs and for suppliers to develop reliability confidence required to accept ultimate product liability requirements 3 to 5 years. (Included within this time frame is that time required for the government and/or railroads to develop total quantity needs and delivery requirements as necessary to establish ultimate production contract details.)

7) Establishment of production facilities, tooling and materials as necessary to begin the required deliveries - 1/2 to 2 years.

6.2.2 Field Implementation

It is recognized that the changeover cycle for any new coupler system will involve a lengthy time cycle. The last major change by U.S. railroads - to the Type "D" coupler system - was completed in 1916 after approximately 23 years in the changeover process. In Japan, a total of 8 years was spent in planning and logistics preparation in order to make a changeover of 46,000 railroad cars during one day in 1925. The U.S.S.R. spent over 10 years in planning and material preparation plus 22 years to complete the changeover to the SA-3 coupler system in 1957. Even discounting a 10-year loss for World War II, over 10 years were used in a changeover involving significantly less than 1 million cars.

It is thus anticipated that a lengthy changeover cycle will be required for full introduction of a new coupler system. The economics of excess inventory and multiplicity of handling equipment alone would tend to rule out a precipitous changeover period.

A complete logistics study should be made to determine the most economical changeover rate which would achieve the optimum balance of minimum inventory and equipment and minimum lost operational time from use of mixed systems. It is recognized, of course, that all new purchased cars should be equipped with the new coupler system. Such new car purchases would be coincidental with the following change sequence.

1) Conversion Sequence: The application of any new coupling system to the entire general freight system would involve a process of sequentially converting different segments of the cars on each rail line. This general sequence might logically be accomplished as follows:

(a) Conversion of each railroad's own in-house cars which are most often pre-blocked and used as grouped units within trains would have the greatest impact for savings to each railroad.

(b) Unit trains are subject to the most frequent service and thus are subject to the greatest number of coupling sequences as a group. Such unit train cars would represent the next largest group for potential savings after change to the new coupler system.

(c) Cars subject to major repair involving couplers would be readily subject to completion of the conversion program with minimum disruption of total service.

2) Automatic Air Connection System: A two-stage introduction for the add-on connection system would appear to offer the most economical phase-in plan.

(a) In the first stage, the mechanical air connector would be added together with a train airline valve which could be operated manually from either side of the car. The standard angle cock and air hose/glad hand would be moved to the other side of the coupler to allow for a regular coupling sequence with nonequipped cars.

(b) In the second stage of the changeover, the required air control system would be added and the remainder of the system for automatic air valve operation would be installed. The installation of the remote uncoupling button and the hydraulic uncoupling operating mechanism could be deferred for a third stage modification should the development of these items lag that of the basic air connector system.

This two-stage introduction approach would provide for the minimum amount of expenditure in the initial stages of application of an automatic coupling system and would provide considerable benefit in the elimination of the need to couple hoses between equipped cars. The second state of applying the valves could be delayed until all cars considered for automatic coupling are equipped with the train line connector.

6.3 DOT/AAR Management Overview

For the successful conversion to a new coupler system, close cooperation and open information channels will be needed among DOT, AAR and railroad industry suppliers and users. Identified below are some specific areas of management responsibility.

An early pronouncement should be made to the railroad supplier community as to the potential for production business which could result from the proposed coupler change program. A clear message was received from this group that they will require a positive statement on the future market potential as a requisite to committing the funds needed to complete new designs.

To aid in supplier development efforts, it is necessary that specifications be changed or clarified as needed to define the allowable variations for new coupler systems. This applies particularly to such areas as allowable changes to air lines, limitations on automatic air connectors, allowable changes to angle cock locations, and others. A concerted effort will be required to oversee the timely processing of needed changes to rules, regulations, and specifications.

Engineering prototype tests should be conducted with full cognizance from the Office of Safety of the Federal Railroad Administration, designated committees of the AAR, designated representatives of the cognizant railway unions, and designated representatives of other interested groups (i.e., OSHA).

A detailed engineering analysis should be made by the appropriate technical groups to establish an agreed upon standard for acceleration of the test schedules required to prove the adequacy of any new coupler design concept. The accelerated test programs should be based on the use of statistically chosen sample sizes and test parameters to achieve the greatest possible technical information in the least time while meeting the desired reliability and safety standards.

300 Copies

Coupling System Design Optimization: A Survey and Assessment of Automatic Coupling Concepts for Rail Freight Cars, Volume I: Executive Summary (Final Report), 1978 - US DOT, FRA